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The Role of University of Nebraska-Lincoln's Biodigester on Sustainable Food Waste Reduction within Selleck Dining Center

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THE ROLE OF UNIVERSITY OF NEBRASKA-LINCOLN'S BIODIGESTER ON SUSTAINABLE FOOD WASTE REDUCTION WITHIN SELLECK DINING CENTER

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Abstract

The University of Nebraska-Lincoln took a major step toward sustainability this past fall when Dining Services installed their first ever biodigester on November 8, 2019 within Selleck Dining Center. The impact this biodigester has had, thus far, is observable in the form of quantitative data collected in the amount of food waste digested by this technology. This study focuses on analyzing collected data from the LFC Cloud database, while also searching for trends and patterns that could further suggest substantial impact and efficiency of the biodigester on food waste reduction and sustainability initiatives within UNL Dining Services. Data Tables and figures within this report aim to visually represent the impact of this biodigester. Broken down by days, weeks, and months, the charts, graphs, and tables produced from the biodigester data are the most in-depth statistical analysis conducted using data from the UNL biodigester. This study serves as an introduction and stimulus project to establish a foundational framework and understanding of the importance and potential for continuing future observation, analysis, and research surrounding the UNL biodigester housed in Selleck Dining Center.

Key Words: biodigester, environmental studies, food waste, sustainability,

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Introduction

Everyday thousands of students at the University of Nebraska-Lincoln enter the dining halls to fill their bellies with food. With five different dining centers, four options for meal plans, and three "Grab-N-Go" shops, there are two questions that come to this one Husker's mind. How much food is wasted every day within these dining halls and how can UNL reduce this impact?

According to an article written by Sean Hagewood of University Communications for UNL, there were 882,340 meal transactions during the spring 2018 semester (Hagewood). Of these 882,340 meals, how many of them included food being dumped into the trashcan? Anyone familiar with the UNL dining system will recognize the routine of placing dirty dishes on a conveyor belt and depositing silverware in the proper containers. That is the known and obvious side of the dining system—the only side that students see and understand.

Unfortunately, few to none of the students eating inside the UNL dining halls are informed of where their dishes and remaining food go after the conveyor belt carries them away. For all they know, Herbie Husker is behind the scenes eating their food scraps in the back of the kitchen. In reality, a lot of the food that students leave on their plates is thrown out and eventually sent to a landfill.

Although the average UNL student does not know where their food waste ends up, it is irresponsible to ignore the impact this food waste is having on both the environment, as well as the stakeholders invested in the institution of UNL. Food waste can have negative consequences on a wide array of factors including financial, social, environmental, and educational initiatives within the university and the broader community. Specifics of these potential concerns and issues will be discussed in depth later on in this document.

According to the United States Environmental Protection Agency, 96% of uneaten food ends up in landfills, which is approximately 21.5 million lbs/year (EPA). The environmental cost of food waste is statistically reported as 3.3 billion tons of greenhouse gases (GHG) produced annually from the nearly 30% of all food that is thrown away (Waliczek). For every 3kg of food that is thrown into the trashcan, 23kg of CO_2 emissions are released into the atmosphere (Oakes).

To address the issue of food waste in a productive and efficient manner, it is vital that UNL begins developing and implementing a plan for reducing food waste within the dining halls. UNL has both a responsibility and the capability to address these pressing concerns. Beyond institutional ethics and financial capacity, UNL has a remarkable opportunity to lead the entire globe in sustainability efforts. By implementing food waste reduction initiatives, UNL will pave the way for institutions to follow suit in adopting efficient and eco-friendly methods of utilizing food waste for good, rather than evil.

As of November 8, 2019, UNL Dining Services has taken a major step in reducing their food waste and promoting sustainable habits within the dining sector. November 8th marked the beginning of an incredibly advanced and brand-new piece of food waste technology operating on campus. This day was the first official operating day for UNL's biodigester in Selleck Dining Center.

Biodigesters accept organic waste materials such as food scraps left on students' plates or uneaten leftovers from the end of the day. These pre- and post-consumer materials are combined with a special enzyme that facilitates further breakdown, or digestion, of food—similar to enzymes in your own stomach that aid in helping to digest food. The end product of this entire process is a form of "grey water"—wastewater that is transported into the sewage system and eventually cycled back into Lincoln wastewater treatment facilities. Simply put, the main function of this biodigester is to convert food waste into a "non-landfill" product, in the form of grey water.

Although this piece of equipment is brand new to campus and has not had sufficient time to earn its credibility or effectiveness, it is important to analyze and discuss the impact it has had thus far to understand and predict future efficiency, sustainability, and potential on UNL's campus. The goal of this research project is to review and assess the biodigester's role on reducing food waste and improving sustainability within Selleck Dining Center. The final product of this study will include a comprehensive review of the following objectives:

- Assess the impact of biodigester thus far, by conducting calculated analysis of collected data
- Identify trends or patterns of biodigester usage observed up until this point
- Visualize the data collected and analyzed with graphs, charts, and figures
- Discuss the potential challenges & benefits of future research and initiatives involving the biodigester, including the possibility of increasing the number of biodigesters on campus

Food waste can have severe and long-lasting negative consequences within the realm of society, education, the economy, and the environment. However, these consequences can be directly combatted either through reduction or complete elimination of food waste. Though there are countless benefits to be discussed and included within this study, the following list of bullet points represent some of the key motivations for pursuing this project, based on values and priorities of those stakeholders involved:

- Financial motivation—less food waste sent to the landfill from dining centers on campus means less money spent by UNL to haul this food waste away.

- Environmental motivation—less food and materials going to the landfill means less CO_2 and other toxic greenhouse gas emissions being released into the atmosphere.
- Educational motivation—implementing a food waste reduction program focused on the biodigester could provide both education and skills to students, faculty, and staff in the form of research, exploration, maintenance, and engagement with this technology.
- Moral/Civic/Social motivation—the presence of a biodigester on campus has the potential to enhance environmental behaviors such as increasing awareness and knowledge of food waste, encouraging personal accountability, fostering environmental stewardship, and significantly reducing food waste habits by shifting the mindset of individuals
- Status motivation—by pursuing biodigester technology, UNL is one of the few universities within the country to prioritize food waste reduction at this level. Continuing with these initiatives could potentially qualify the university for recognition of their efforts, prestigious attention, elite sustainability status and awards, and a progressive reputation for environmental consciousness (both within the BIG10 conference and globally).

The benefits highlighted above are just a few of the many opportunities for advancement and progress that stem from developing and implementing a food waste reduction initiative on UNL's campus. By observing and analyzing the function, productivity, and impact of UNL's first biodigester, this project will be contributing greatly to the available information regarding the effectiveness of such a food waste initiative. Exploring the usefulness and influence of biodigesters and other food waste reduction techniques will not only contribute to a more sustainable, conscientious, responsible, and educated population on campus, but also to a healthier and more resilient collaborative community within the city of Lincoln.

Of course, it would be naive to dismiss the financial and economic benefits of such a project for UNL. Several universities across the globe have tested and implemented food waste reduction programs that have proven to provide significant economic benefits. According to "Environmental and economic analysis of an in-vessel food waste composting system at Kean University in the U.S." (Dongyan Mu), composting efforts at this institution had the potential to generate a profit of $13,200 annually by selling veggies grown straight from their compost. When they included educational and environmental benefits, revenue increased to $23,550 per year. In this same study, it was found that lower impacts were created in fossil fuels, GHG (greenhouse gas) emissions, eutrophication, smog formation, and respiratory effects. However, higher impacts were associated with ozone depletion, acidification, and ecotoxicity. This information supports the claims and projections for both economic and environmental benefits related to reducing food waste on campus. It also acknowledges the potential drawbacks and challenges of a specific method such as composting.

The logistics of composting, in terms of what method and approach is best fit for our campus, can be daunting to consider. Based on the resources, space, budget, intensity of labor, and overall goals of a composting program, determining the best system to implement to ensure optimum results and benefits can be difficult. As such, the implementation and function of the Selleck biodigester has been a unique and relatively hassle-free method of observing how much food waste can be eliminated within one specific dining hall on campus.

Implementing some sort of food waste reduction system within the UNL dining halls is not only necessary, but urgent. "The Relationship between a campus composting program and Environmental Attitudes, Environmental Locus of control, Compost Knowledge, and Compost Attitudes of College Students" provides a unique perspective of this idea through the lens of *environmental locus of control*. The article defines this term as “the belief that an individual’s actions play a direct role in the result of any affair” (Waliczek). Beyond educating students within the classroom, this concept is a foundational goal of higher educational institutions such as UNL. Implementing food waste reduction efforts on UNL’s campus will allow this concept to happen naturally by encouraging students to explore and strengthen their role in the campus community. By acknowledging and recognizing the importance of individual impact on the food waste system, UNL has the chance to directly influence and inspire the community to think bigger than themselves. These efforts are absolutely imperative for developing and promoting responsible, engaged, and empowered individuals within the UNL community.

Institutions and universities across the globe have been successful through the implementation of various food waste reduction programs. Ohio University is home to the largest in-vessel composting system on any college or university campus in the nation. Texas State University was able to divert 57 tons of food waste over a period of just three years (Waliczek). Two different studies done at university campuses in Malaysia relay the potential environmental benefits of reducing food waste. “Composition of Solid Waste in a University Campus and its Potential for Composting” (Tiew) researches the solid waste generation at the Universiti Kebangsaan Malaysia (UKM). This research aimed to quantify waste generation and composition by the following groups: organics, papers, plastics, glass, metals, e-waste, and others. It even took steps to include estimations of factors such as moisture content, density, pH, and Carbon/Nitrogen ratio (C/N ratio). Results from this study found that the monthly average solid waste generation on this campus was 137.57 tons. In “Greenhouse Gas Emission of Organic Waste Composting: A case study of Universiti Teknologi Malaysia Green Campus

Flagship Project" (Kamyab), a study is conducted that attempts to quantify the GHG emissions produced from each step of the composting process on their campus.

From extensive research and literature reviews regarding food waste reduction efforts within other campuses and institutions, it is apparent that every system and method has its pros and cons. Through observation and analysis of the Selleck biodigester on UNL's campus, this study will attempt to highlight the effectiveness, impact, strengths, and weaknesses of such a system. In doing so, UNL can better understand and evaluate the benefits and challenges with implementing more biodigesters on campus to reduce food waste and improve sustainability.

Although this topic may not be prevalent within the current population of students on UNL's campus, it is a subject that directly affects all those who step foot in the UNL dining halls. Not only is this topic incredibly relevant to the challenges our planet is facing with a changing climate, but it has the potential to provide the University of Nebraska-Lincoln with the opportunity to be a leader in environmental stewardship on university campuses. Reducing food waste on campus can have financial, environmental, social, and educational benefits for the students, faculty, and staff of UNL, as well as the entire institution as a whole. In addition to UNL, this project could also have serious benefits and possibilities for the surrounding community of Lincoln and beyond—the entire planet.

Materials and Methods

The primary material that will be used to conduct this study is the biodigester housed within the Selleck Dining Center. The biodigester was installed in September 2019 and officially up and running by November 8. 2019. This specific model is LFC-200 and it is connected 24 hours a day 7 days a week. The biodigester waste capacity is 440 pounds (200 kg) per day and uses approximately 140 gallons of water per day.

Data is constantly being collected and stored for this biodigester via the LFC Cloud database. Through the cooperation and generosity of UNL Dining Operations, including Dave Annis (Director of UNL Dining) and Gina Guernsey (Manager of Selleck Dining Center), access to view and utilize collected data for this project has been granted, with an understanding that it will be used for research and analysis purposes. This online data collection cloud stores data collected by the biodigester from the very first moment it was installed and began running on November 8th. As such, the available data can be reviewed and analyzed from the very beginning stages of this machine's contribution to Selleck Dining Center up until the current date.

The collected data from Selleck's biodigester is more than just the amount of waste that is being input into the system—"digested". LFC Cloud provides an organized display of data that can be broken down by hour, day, week, month, or year. This data includes waste digested (kg) and time of digestion, carbon reduction (tonne), number of times the door was open, and average digestion (kg/day). This information is presented primarily in a numerical fashion, given with specific measurements, weights, times, amounts, rates, and values. However, the information is also portrayed visually through graphs and charts that can be user-operated to indicate range of time that would be best utilized—day, week, month, year. Within the graphs, values for maximum input, minimum input, average, and total can be obtained.

The LFC Cloud software affiliated with this particular biodigester allows this research project to be heavily dictated by numbers. With such a data-driven research design and approach, the main procedures and methods of this study involve quantitative analysis of statistics and values, as dictated by the LFC Cloud program. Though the computer and materials do a bulk of the heavy lifting in regard to data collection and organization, the majority of data processing, analysis, and visual representation for this project was conducted outside the software.

The sampling of data for this research is done automatically by the inputs into the system. Inputs include food scraps from post-consumer materials and an enzyme, utilized to facilitate breakdown of organic material. Certain inputs such as bones, shells, dairy products, and grease are not allowed into the biodigester to ensure proper functioning and maintenance of the machine. All students who ate in Selleck Dining Center between the time period of November 8, 2019 and March 31, 2020—assuming they contributed to post-consumer materials in the form of food waste—are included in the sample size of this study. It is not known the exact number of students who contributed inputs to the system, due to the unknowns of whether each student who entered the dining hall contributed "usable" materials for the biodigester. However, sampling was not dictated by factors other than appropriate and usable materials that could be input and digested by the biodigester. Sampling was also not limited or controlled in any other manner besides appropriate inputs and maximum capacity for the biodigester.

Data is automatically uploaded to the LFC Cloud on a second-by-second basis, providing constant, consistent, and up-to-date availability and access to collected information. The website for LFC Cloud also includes status updates for when the biodigester was last seen online, location of IP address (city, country, and Google spot), current waste (kg and %), amount digested today, usage today, status of water (on/off), door positioning (open/closed), time of last operation and power on, and time of last machine start. All of these status updates, as well as service records for when the biodigester was last calibrated or maintained are accessible. Finally, information regarding diagnostics and settings can also be viewed, such as drum and washout water status, sensors, motor and heat currents, drum and controller temperature, and more.

Data processing and analysis will be conducted using statistical methods for calculating and presenting trends and patterns from the data. These trends and patterns will be portrayed in a simplified and usable product for application to discussion, recommendations, and conclusion. To present the huge depth of information available via LFC Cloud in a simplified, user-friendly manner, the final product of this project will aim to represent the vast expanse of data through only two windows: amount of food waste digested (diverted) and amount of carbon dioxide reduced. By representing the data through the lens of these two observable factors, readers and future contributors to this research will be provided with clear numbers and statistics, as well as visual aids in the form of graphs, charts, and tables.

These simplified figures will be represented using the collected data to highlight and review values such as averages, totals, minimums, and maximums. While some trend analysis will be included within this study, the limited availability and consistency of the collected data reduces the depth and pertinence of this analysis. As such, most trend and pattern occurrences and observations within this study will not be sufficient to make definitive statements about the tendencies and predicted behavior of the biodigester. Going forward, those who decide to continue research and efforts within this realm of study should absolutely consider pursuing and including a more in-depth trend analysis. A more conclusive trend analysis will allow future research to form an accurate depiction of the biodigester's impact and potential.

Acknowledgement of Limitations

Limitations of this project must be clearly acknowledged and addressed upfront. The primary limitations, or constraints, to the efforts related to this research are identified in further detail, but not exhaustively. Several factors have created a notable challenge in producing both an ideal volume and consistent representation of data within this study.

First, the sample size of only one dining hall (Selleck Dining Center) results in a smaller scope of available information and data that can be accurately applied to the overall campus. To account for the sampling size of only one dining hall, the purpose and objectives of this project have been defined to directly address and evaluate the effectiveness of the biodigester at Selleck Dining Center, and not the entire campus of UNL.

Additionally, the limitation of minimal data was compounded by a relatively short functioning and observational period for the biodigester. Due to late installation of the biodigester (starting in November), as well as several disruptions in data collection, the amount of time available for usable data analysis is relatively short. Extended university breaks (Thanksgiving break, Winter break, Spring break, etc.) and the recent effects of the COVID-19 pandemic are the most notable disruptions in data collection from the study period. The amount of data available for analysis has been heavily affected and influenced by such events. This is largely due to the fact that less students were on campus during these times to contribute inputs to the biodigester in Selleck Dining Center. Not only have these events significantly reduced data, but they have also created gaps of understanding within the trends and patterns created by the usage of this biodigester.

Due to the constraints and restrictions discussed above, the overall findings of this study should be evaluated with these significant limitations in mind. All components of this study are not to be distinguished or labeled as definitive evidence for either the success or failure of the Selleck biodigester. The scope of limitations within this project prevent the development of conclusive statements and predictions. Rather, conclusions and suggestions from this project should be used as general information for pursuing future research and observation of the effectiveness of the Selleck biodigester.

Results

The results of this study will be presented in the context of the four primary objectives provided at the beginning of this report. First, to discuss the impact that the Selleck biodigester has had, thus far, data collected from the LFC Cloud database for the entirety of the observation period was carefully compiled. Second, this data was reviewed and analyzed to identify trends and patterns that may exist. Upon thorough review, intentional calculation, and final evaluation, the information provided from data and trend analysis was utilized to create visual representations of the statistics in the form of graphs, charts, and tables. Finally, these objectives and results will be compiled to facilitate discussion regarding the potential challenges & benefits of future research and initiatives involving the biodigester.

All graphics from this project were generated using data from the LFC Cloud database and tools from Microsoft Excel. Results will be displayed in the form of seven Data Sheets and four figures. Data Sheets will be attached to the end of this report (found in Appendices) for review and reference, while the figures are imbedded within the body of this text for ease of access and application to the results, discussion, and summary.

The observation period for the research focus identified within this project spanned the length of five consecutive months: November ('19), December ('19), January ('20), February ('20), and March ('20). **Figure 1** and **Figure 2** display a monthly breakdown of the amount of food waste digested (lb) by the Selleck biodigester each month of the observation window. The observed months within this study are each represented by an individual color and numerical value, indicating the amount of waste digested (lb) during that month. An overall sum of monthly digestion values is represented by "Total Waste" in the center of **Figure** 1. A bar graph representing the same data is displayed in **Figure 2.**

Figure 1: Each month within the observation period of this study is represented by its own color, identified in the legend on the right. The amount of waste digested (lb) each month is identifiable by the white numbers within each colored ring. An overall sum of the total waste digested during the time period of this study is shown in the center of the figure.

Figure 2: The graph above represents the same data found in **Figure 1**. Each month within the observation period of this study (x-axis) is represented with the amount of waste digested (y-axis) noted above the appropriate bar.

Each month included in this study has its own Data Sheet, found at the end of this report in “Appendices” (November= **Data Sheet 1**, December= **Data Sheet 2**…). The Data Sheets include significant observations, such as highest and lowest values for each month. They also include weekly highs and lows, values during notable events and disruptions during the semester (Thanksgiving, Winter, and Spring breaks, MLK Day, COVID-19 announcement, etc.), and sums for various weeks and weekends throughout the study. This representation of the collected data, in the form of data sheets, is helpful when attempting to identify trends, patterns, and form other conclusions or predictions for the future.

Data Sheet 6, “Overview of Yearly and Monthly Statistics for Selleck Biodigester”, contains general statistics such as the total waste digested since installation, highest values of waste digested (per day and per week), and data used to create **Figures 1** and **2**. All of the statistics found on this data sheet are notable when applying values to discussion.

Data Sheet 7, “Average Values of Waste Digested by Weekday”, contains calculated averages of the amount of waste digested each day of the week. These averages are represented in two different forms, as shown in **Figure 3**. The total average value of waste digested, represented by the blueline, is displayed for every weekday within the observation period (x-axis). The average value of waste digested, excluding the three lowest values, is represented by the orange line. All of the data used to create **Figure 3** can be found within **Data Sheet 7**. The importance of representing these values will be further examined in the “Discussion” section below. Explanation and reasoning for removing the three lowest values, displayed by the orange line in **Figure 3**, will also be explored in more depth.

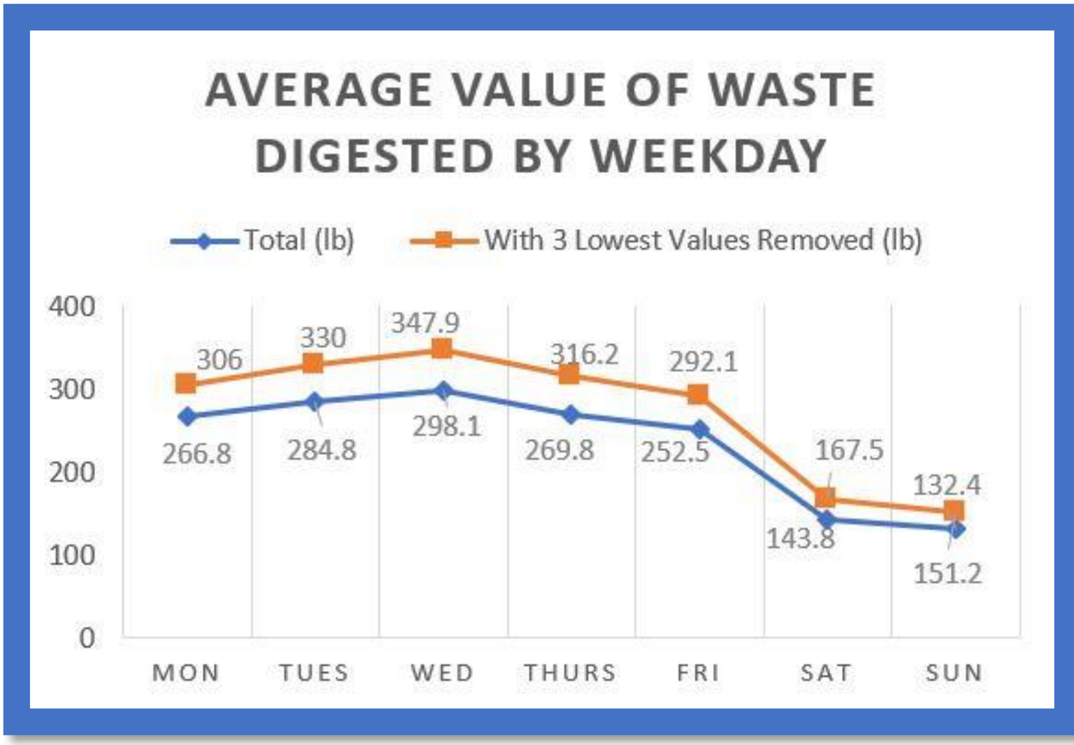

Figure 3: The graph above represents the average value of waste digested (y-axis) for every weekday within the observation period (x-axis). This average is represented in two different ways by the blue and orange lines. The blue line shows the total average value of waste digested by weekday, while the orange line displays the average value, excluding the three lowest values. All weekday averages are displayed numerically below or above the points on the graph.

The monthly and weekly data shown in the three figures above, when collected for a longer period of time, could show significant and more definite trends in usage of the biodigester. However, as **Figure 4** attempts to address below, the inconsistency of data collected for this study provides serious reservations when attempting to predict or define any sort of pattern or trend in the values. In **Figure 4**, the green bars represent the highest recorded values of waste ingested (lb) per month (x-axis), while the blue bars represent the lowest recorded values of waste ingested (lb) per month. The variation and irregularity in the values presented within this figure justify the need for continued observation, data collection, and further research.

Figure 4: The graph above represents the monthly highs and lows of waste digested (y-axis) for each month (x-axis) within the observation period of this study. The green bars display the highest recorded values of waste digested (lb) per month, while the blue bars present the lowest recorded values of waste digested (lb).

Discussion

Figure 3 displays the weekly trend in amount of food waste digested by the biodigester. This trend shows higher values at the beginning of the week (starting on Monday), which can also be seen in the **Data Tables** found at the end of this report. Many of the "highest recorded days of digestion" are recorded on Mondays, Tuesdays, and Wednesdays. This is further confirmed when looking at **Figure 3**, as the graph shows values peaking on Wednesdays. A look at the **Data Tables** will also confirm this observation—many of the highest recorded values for waste digested are on Wednesdays. The trend continues as the week progresses and values decrease toward the weekend, with the lowest values overwhelmingly on Saturdays and Sundays. Again, referencing the **Data Tables** will confirm this pattern of "lowest recorded days of digestion" often occurring toward the end of the week (Thursdays & Fridays) and especially over the weekend (Saturdays & Sundays). This graph suggests a pattern in the usage of the biodigester within Selleck Dining Center. However, several outliers and values do not follow this consistent trend and can be used to justify the need for further data collection and research within trend analysis for the biodigester.

The purpose of representing the data from **Figure 3** in two different types of averages aims at addressing this very idea of outliers and inconsistencies. To account for these irregular data points, the orange line represents a different average from the blue. While the blue line is a standard average with all data points included, the orange line removes three of the most obvious outliers and irregular values included in the data collection for each weekday. This attempts to acknowledge and correct inaccurate values portrayed by disruptions in data, such as university breaks or closures. These interruptions in data collection may result in a skewed average, though they do not appear to affect the overall trend represented in **Figure 3.**

As mentioned earlier, **Figure 4** represents the inconsistency of the lowest and highest values recorded during each month of observation. While every month (except March) have values in the 400s for "highest recording of waste digested", they do not display that same consistency for "lowest recording of waste digested". **Figure 4** looks at the data on a monthly basis of highs and lows, but Data Sheets 1-5 display similar information on a weekly basis. When reviewed on a shorter timeframe, weekly highs and lows appear to be just as inconsistent. The sporadic nature of these values, either weekly or monthly, seem to suggest no identifiable trend in the numerical value associated to highs and lows within the observation period. However, it is possible this trend could present itself with further data collection and observation in the future. Additionally, the less interruption there is when gathering values for this specific study, the better. As such, choosing a dining hall that continues to serve students over extended university breaks would be best.

While it is evident that more research with the biodigester will produce greater understanding of its benefits on campus, there are certainly other options for sustainable food waste reduction that can be further researched and explored. For the purpose of this study, focus will be solely placed on the effectiveness of the biodigester technology. However, there is great value in exploring all potentially beneficial and efficient methods of food waste reduction, such as composting. Composting is similar to a biodigester in that it aides in breaking down, or decomposing, organic materials. Where these two methods differ is in the output of the overall process. For this specific biodigester, as mentioned previously, the output product is a form of grey water that is cycled back into the Lincoln sewage system and will eventually be delivered to a wastewater treatment facility. Composting produces a final product in the form of fertilizer to be potentially reused and repurposed as soil or other nutrient rich material.

Beyond the task of identifying the most efficient, sustainable, and beneficial method of food waste reduction, it is equally important to address how and why food waste is being produced in the first place. This study does not focus on environmental behaviors, attitudes, tendencies, or habits of individuals contributing to food waste on UNL's campus. These factors and considerations are all extremely relevant and important to reducing the amount of food waste that must eventually be dealt with later down the line. The United States Environmental Protection Agency (EPA) identifies "source reduction and reuse" as the most valuable solution to food waste within their "Food Recovery Hierarchy". Efforts to educate others on and research food waste should, therefore, highlight source reduction as the top priority. To put that in the context of this study, the biodigester running within Selleck Dining Center is a method for dealing with food waste after it has been produced or generated by the students. Biodigesters, composting, and other methods of handling food waste are all methods of diversion—getting rid of a problem that already exists. A more responsible, beneficial, and productive reaction to the issue involves eliminating the risk factors and contributing behaviors that create the problem in the first place.

It is important to recognize that the output product of this biodigester produces another source of "waste" in the form of wastewater. The scale and severity of waste produced from this grey water, compared to the otherwise food waste that would be transferred to a landfill, is not the focus of this study. However, it is a very important and worthwhile element of future research when considering the potential drawbacks of biodigester technology. For instance, future research should consider the level of environmental harm or impact that the grey water ejected from this biodigester could be contributing to the Lincoln sewage system and overall water cycle. Addressing this concern is vital to understanding the true impact of the biodigester.

Summary and Conclusions

In the short amount of time the Selleck biodigester has been active, it has digested over 30,078 lb of food waste and reduced over 127,867 lb of carbon dioxide (LFC Cloud). These reductions in carbon dioxide and food waste have both environmental benefits, in curbing greenhouse gas emissions, and educational opportunities for the UNL community of students, faculty/staff, and members of the Lincoln community. The impact that this biodigester has already had, though relatively hard to assess and definitively quantify, has displayed reason and justification for continuing to research and observe its value on campus.

The research focus of this study was to review and assess the role of UNL's biodigester on food waste reduction and sustainability within Selleck Dining Center. Utilizing collected data from the LFC Cloud software (PowerKnot), values were reviewed, analyzed, and calculated to further evaluate trends, patterns, and impact of the biodigester. Quantities of food waste digested were represented in daily, weekly, and monthly timeframes to assist in visual representations of the data. Microsoft Excel was then used to further visualize this data in the form of charts, graphs, and tables. Finally, data and trend analysis, as well as visual figures, were used to evaluate the impact UNL's biodigester has had thus far, as well as suggest further avenues of research and continued observation.

The results of this study suggest that, since installation, the UNL biodigester has had a notable and quantifiable impact on reducing food waste within Selleck Dining Center that otherwise would have been sent to the landfill. Additionally, the elimination of this landfill material, in the form of several thousand pounds, also eliminated carbon dioxide emissions that would have been generated to transport and process the food waste digested by this technology. Though the trend analysis portion of this study is somewhat inconclusive, the potential to develop stronger identification of trends and patterns is likely with continued research.

Utilizing this study for future research and educational initiatives will improve understanding and awareness of the efforts UNL has made to reduce food waste on campus. This study should be continued in more depth, with specific focus on how the scientific data and statistics from the biodigester can be best utilized to convey information regarding sustainability efforts and importance to students, faculty/staff, stakeholders, decision-makers, and members of the public. People within the UNL and Lincoln community need the valuable and influential information this type of study provides in an accessible and digestible manner. As research surrounding this topic continues in the future, attention to user-friendly materials and engaging opportunities should be prioritized.

This biodigester has been used by multiple student organizations, including Sustain UNL, and has been included in very active discussions for several events and initiative on campus. In this manner, the Selleck biodigester has already started to generate educational and stimulating discussion, activity, involvement, and engagement from the students and community of UNL. Opportunities to continue this education and environmental awareness are many. As students become more aware of the biodigester's presence on campus, they can be encouraged to learn more about their personal contribution to and impact on reducing food waste on campus.

The LeanPath program will be another great method for engaging students on the discussion of food waste reduction and sustainability within the dining halls. Unfortunately, this data was not yet available to connect with this study. However, future collaboration with these two topics would be highly beneficial and applicable to both research and educational initiatives. Both the LeanPath program and the biodigester help to quantify the amount of food waste that exists from operations within the dining halls. Their combined data and analysis could prove extremely valuable for further assessing sustainable initiatives within UNL Dining.

Though the focus of this particular study is on evaluating the biodigester installed on campus, considering other options for handling food waste (such as composting) is strongly recommended and encouraged. As a research and education institution, UNL has the responsibility and expectation to dive deep into all potential and promising options that exist in the realm of food waste reduction. With this responsibility, also comes the task of evaluating why and how food waste is produced in the first place. As mentioned in the discussion section of this report, source reduction is the most efficient and impactful method for reducing food waste.

UNL should continue to investigate student behavior, values, and tendencies that are affiliated with food waste and work to identify and address these activating contributions to the food waste issue. Proactive and preventative measures will be most successful, in the long run, for reducing food waste on UNL's campus.

Addressing the potential expansion and increase in the number of biodigesters on campus is, for the terms of this study, somewhat uncertain. While it should not be completely dismissed to install biodigesters in every dining hall across UNL, this study cannot definitively recommend such action either. Since the research from this study focuses primarily on the first few months of the biodigester's installation, it is still in the "piloting" phase of a much longer process. This piece of equipment is worthy of more time, data, observation, and research in order to justify its impact, benefits, and sustainable contributions to the campus. There is no guarantee from the observation and data collection of this study that biodigesters are the best option for campus wide food waste disposal. Other methods, tools, and systems should continue to be researched and compared to the conclusions of this study to determine future action regarding the implementation of more biodigesters on UNL's campus.

Though trends and patterns are not as regular or obvious at this moment in time, it is likely that they will present themselves more consistency as time goes on. The longer this biodigester is utilized by University Dining, the more obvious its trends, patterns, benefits, and impact will become. As these factors start to present themselves more fully through the continual usage of the biodigester, broader concepts such as efficiency, productivity, and sustainability can be addressed as well. Thus, the Selleck biodigester is a very important and worth-while subject for continued research, as it is a very engaging and educational form of reducing food waste and improving sustainability at UNL.

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Appendices

Data Sheet 1: Significant observations for the month of November 2019

- 11/08: First day up and running; Beginning of data collection for this study
- 11/09-11/10: First weekend up and running, 159 lb digested
- 11/10 (Sunday): Second lowest recording of waste digested this month @ 6 lb
  - Lowest recording was 0 lb on Thanksgiving 11/28/19
- 11/11-11/15: First full week up and running; Total waste digested this week= 1,528 lb
  - Highest day of week: 11/13 (Wednesday) @ 366 lb
  - Lowest day of week: 11/15 (Friday) @ 181 lb
- 11/18-11/22: Second full week up in running; Total waste digested this week= 1,578 lb
  - +50lb from first week total
  - Highest day of week: 11/20 (Wednesday) @ 356 lb
  - Lowest day of week: 11/18 (Monday) @ 264 lb
- 11/23-11/24: Third weekend up and running; Total waste digested this weekend= 290 lb
  - Highest recorded weekend in November
- 11/25-11/29: Third full week up and running; Total waste digested this week= 650 lb
  - Highest day of week AND Highest day of the month: 11/25 (Monday) @ 409 lb
  - Lowest day of week AND Lowest day of the month: 11/28 (Thursday—Thanksgiving) @ 0lb
- Thanksgiving break (11/27-11/30): Total waste digested= 84 lb

Data Sheet 2: Significant observations for the month of December 2019

- 12/01: Thanksgiving Break (Sunday): 111 lb digested
  - Lowest day of the month
- 12/02-12/06: First full week of December; Total waste digested this week= 1,684 lb
  - Highest day of week: 12/03 (Tuesday) @ 384 lb
  - Lowest Day of week: 12/02 (Monday) @ 293 lb
- 12/07-12/08: First full weekend of month; Total waste digested this weekend= 261lb
- 12/09-12/13: Second full week of December; Total waste digested this week= 1,840 lb
  - Highest day of week AND Highest day of the month: 12/10 (Tuesday) @ 463 lb
  - Lowest day of week: 12/13 (Friday) @ 303 lb
- 12/14-12/15: Second full weekend of month; Total waste digested this weekend= 427 lb
  - 12/14 (Saturday): Second lowest day of the month @ 117 lb
    - Lowest recording was 111 lb on 12/1 over Thanksgiving break
- 12/16-12/20: Last recorded week of December before Winter Break (Finals week); Total waste digested this week= 1,281 lb
- Winter Break (12/21-12/30): Total waste digested= 0 lb

Data Sheet 3: Significant observations for the month of January 2020

- Winter Break (1/01-1/12): Total waste digested= 140 lb
  - 1/01-1/03: First week of Winter Break this month; Total waste digested= 20 lb
  - 1/04-1/05: First weekend of Winter Break this month; Total waste digested= 0 lb
  - 1/06-1/10: Second week of Winter Break this month; Total waste digested= 37 lb
  - 1/11-1/12: Second weekend of Winter Break this month—first weekend before classes resume; Total waste digested= 83 lb
- 1/13-1/17: First full week back to classes after break; Total waste digested= 1,726 lb
  - Highest day of week: 1/17 (Friday) @ 381 lb
  - Lowest day of week: 1/13 (Monday) @ 289 lb
- 1/18-1/19: First weekend back after classes resume; Total waste digested= 94 lb
  - 1/19 (Sunday): 0 lb digested
- 1/20-1/24: Total waste digested for the week= 1,590 lb
  - 1/20 (MLK Day): no classes for MLK holiday; Total waste digested= 120 lb
  - 1/21-1/24: 4-day week due to MLK holiday; Total waste digested= 1,470 lb
  - Highest day of week AND Highest day of the month: 1/23 (Thursday) @ 453 lb
  - Lowest Day of week: 1/20 (Monday) @ 120 lb (MLK Day)
- 1/25-1/26: Last weekend of January; Total waste digested= 378 lb
- 1/27-1/31: Second and final full week of January; Total waste digested= 1,686 lb
  - Highest day of week: 1/29 (Wednesday) @ 400 lb
    - Second highest day of the month (Highest day is 1/23 @ 453 lb)
  - Lowest Day of week: 1/27 (Monday) @ 307 lb

Data Sheet 4: Significant observations for the month of February 2020

- 2/01-2/02: First weekend of February; Total waste digested= 356 lb
    - 2/02 (Sunday): Lowest day of the month (tied with 2/16) @ 144 lb
        - Super Bowl Sunday
- 2/03-2/07: First week of February; Total waste digested= 1,691 lb
    - Highest day of week: 2/05 (Wednesday) @ 398 lb
    - Lowest day of week: 2/06 (Thursday) @ 281 lb
- 2/08-2/09: Second weekend of February; Total waste digested= 317 lb
- 2/10-2/14: Second week of February; Total waste digested= 1,986 lb
    - Highest day of week AND Highest day of the month: 2/13 (Thursday) @ 441 lb
    - Lowest Day of week: 2/10 (Monday) @ 357 lb
- 2/15-2/16: Third weekend of February; Total waste digested= 357 lb
    - 2/16 (Sunday): Lowest day of the month (tied with 2/16) @ 144 lb
- 2/17-2-21: Third week of February; Total waste digested= 1,724 lb
    - Highest day of week: 2/18 (Tuesday) @ 383 lb
    - Lowest day of week: 2/20 (Thursday) @ 310 lb
- 2/22-2/23: Fourth and final weekend of February; Total waste digested= 428 lb
    - 2/22 (Saturday): 275 lb digested=highest Saturday of the month
- 2/24-2/28: Fourth and final week of February; Total waste digested= 1,787 lb
    - Highest day of week: 2/26 (Wednesday) @ 387 lb
    - Lowest day of week: 2/24 (Monday) @ 315 lb
- 2/29 (LEAP DAY): Final day of February; Total waste digested= 232 lb

Data Sheet 5: Significant observations for the month of March 2020

- 3/01: First day of March (Sunday); Total waste digested= 210 lb
- 3/02-3/06: First week of March; Total waste digested= 1,671 lb
    - Highest day of week AND Highest day of the month: 3/06 (Friday) @ 366 lb
    - Lowest day of week: 3/02 (Monday) @ 304 lb
- 3/07-3/08: First full weekend of March; Total waste digested= 316 lb
- 3/09-3/13: Second week of March; Total waste digested= 1,502 lb
    - Highest day of week: 3/10 (Tuesday) @ 320 lb
    - Lowest day of week: 3/13 (Friday) @ 289 lb
    - 3/12 (Thursday): COVID-19 Announcement—classes moving to online format; Total waste digested= 290 lb
- 3/14-3/15: First weekend after COVID-19 announcement; Total waste digested= 295 lb
- 3/16-3/20: NO CLASSES DUE TO COVID-19; Total waste digested= 601 lb
    - Highest day of week: 3/16 (Monday) @ 181 lb
    - Lowest day of week: 3/19 (Thursday) @ 82 lb
- 3/21-3/29: Spring Break; Total waste digested= 750 lb
    - 3/21 (Saturday): Lowest day of the month @ 28 lb
- 3/30-3/31: First week after Spring Break and first week of virtual classes due to COVID; Total waste digested= 138 lb
    - 3/31 (Tuesday): Last day of march; Total waste digested= 33 lb
        - Second lowest day of the month @ 33 lb (Lowest day was 3/21 @ 28 lb)

<u>Data Sheet 6: Overview of Yearly and Monthly Statistics for Selleck Biodigester</u>

Yearly Statistics Breakdown:

- ➔ Total Waste Digested (Since Installation 11/8/19)
    - o 10,103 lb (2019) + 19, 975 lb (up until 4/1/20) **= 30,078 lb**

- ➔ Highest Values of Waste Digested—over entire observation period (11/8/19-3/31/20)
    - Highest Day: 12/10 (Tuesday) @ 463 lb
    - Highest Week: 2/09-2/15 @ 2,363 lb

Monthly Statistics Breakdown:

- ➔ 5 months of data (November, December, January, February, March)
- ➔ Waste Digested by Month:
    - o November: 4,498 lb
    - o December: 5,605 lb
    - o January: 5,614 lb
    - o February: 8,878 lb
    - o March: 5,483 lb

- Highest month: February (8,878 lb)
- Lowest month: November (4,498 lb)

Data Sheet 7: Average Values of Waste Digested by Weekday

Monday: 266.789 lb

Total lb: 5,069

# of days included in calculation: 19

With 3 lowest values removed: 4,896/16= 306 lb

Tuesday: 284.842 lb

Total lb: 5,412

# of days included in calculation: 19

With 3 lowest values removed: 5,280/16= 330 lb

Wednesday: 298.056 lb

Total lb: 5,365

# of days included in calculation: 18

With 3 lowest values removed: 5,219/15= 347.933 lb

Thursday: 269.833 lb

Total lb: 4,857

# of days included in calculation: 18

With 3 lowest values removed: 4,743/15= 316.2 lb

Friday: 252.474 lb

Total lb: 4,797

# of days included in calculation: 19

With 3 lowest values removed: 4,674/16= 292.125 lb

Saturday: 143.778 lbs

Total lb: 2,588

# of days included in calculation: 18

With 3 lowest values removed: 2,512/15= 167.467 lb

Sunday: 132.353 lb

Total lb: 2,250

# of days included in calculation: 17

With 3 lowest values removed: 2,117/14= 151.214 lb